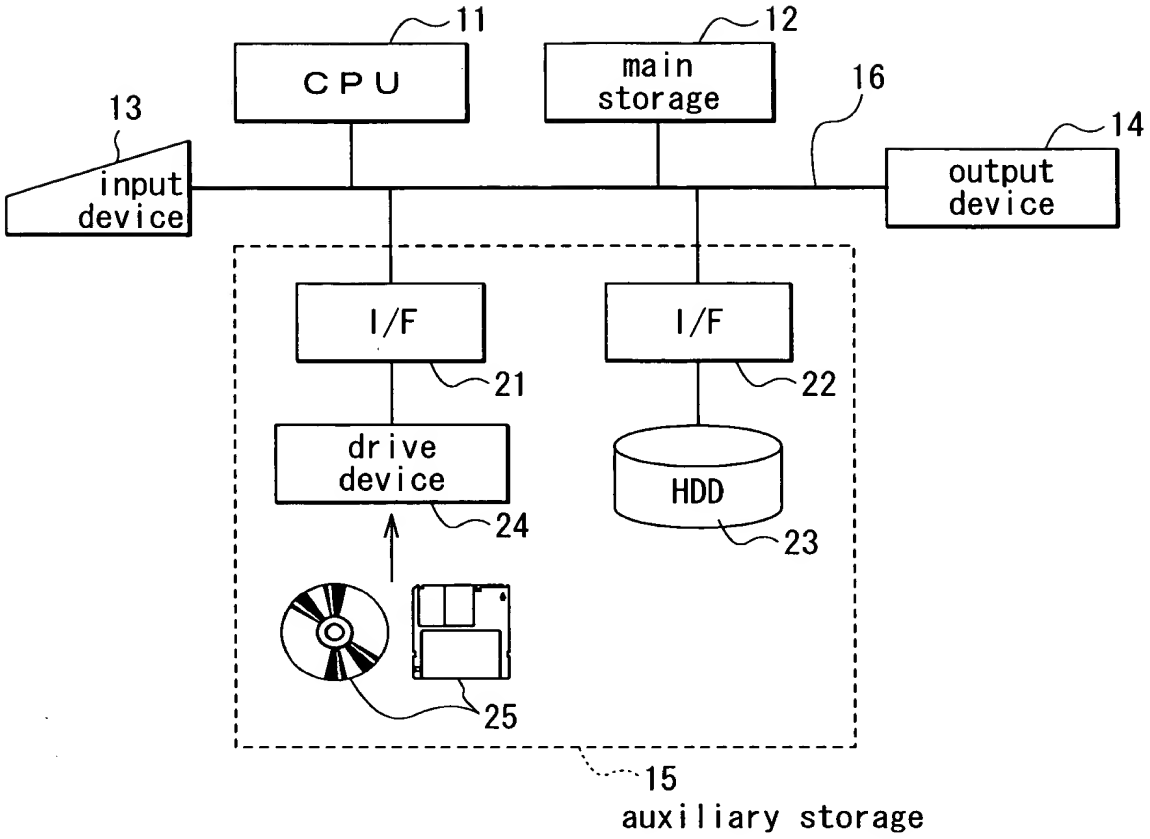
11
CPU
12
main storage
16
13
input device
14
output device
I/F
I/F
21
22
drive device
HDD
24
23
25
15
auxiliary storage

FIG. 1

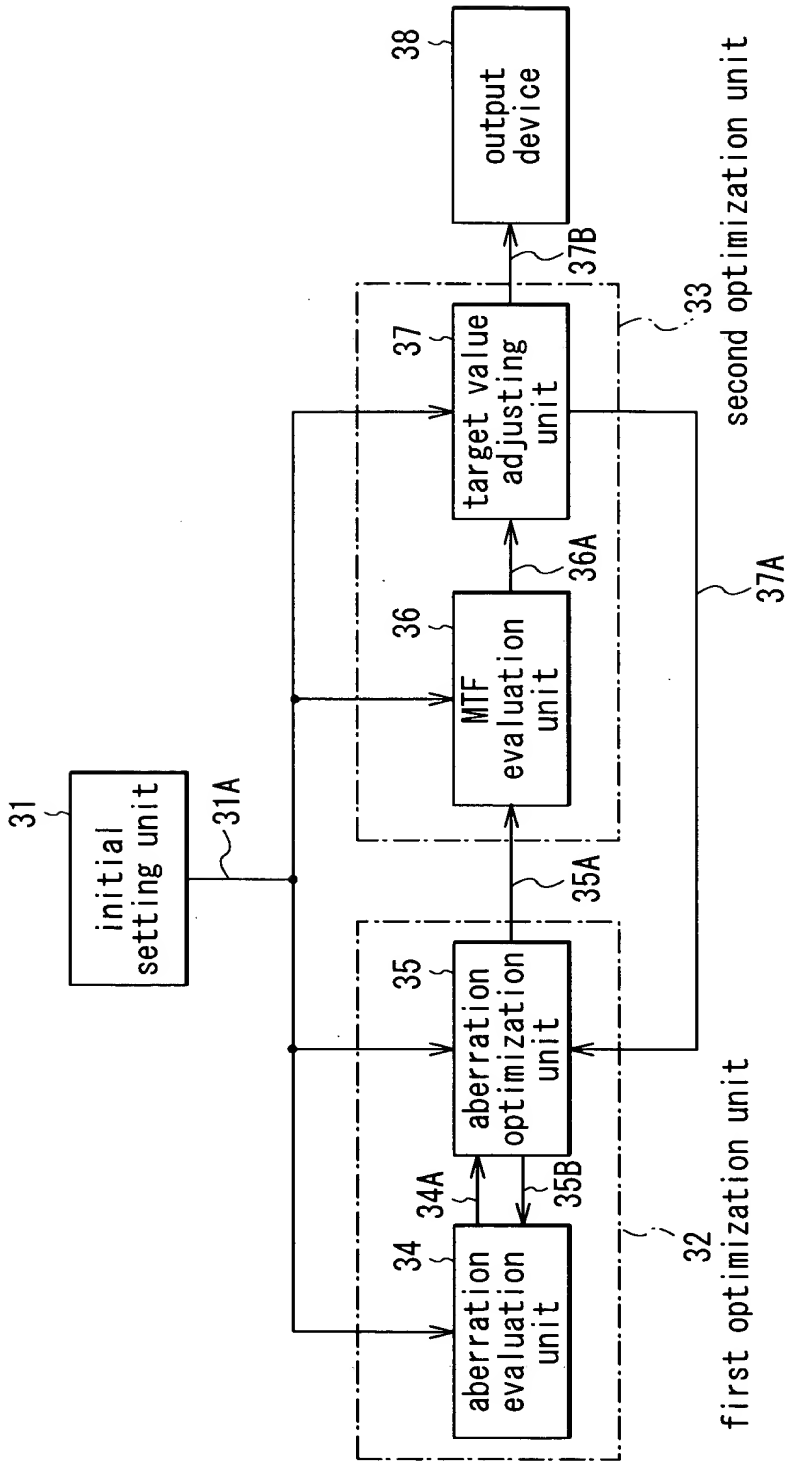
31
initial setting unit
31A
34
aberration evaluation unit
34A
35B
35
aberration optimization unit
35A
36
MTF evaluation unit
36A
37
target value adjusting unit
37B
38
output device
37A
32
first optimization unit
33
second optimization unit

FIG. 2

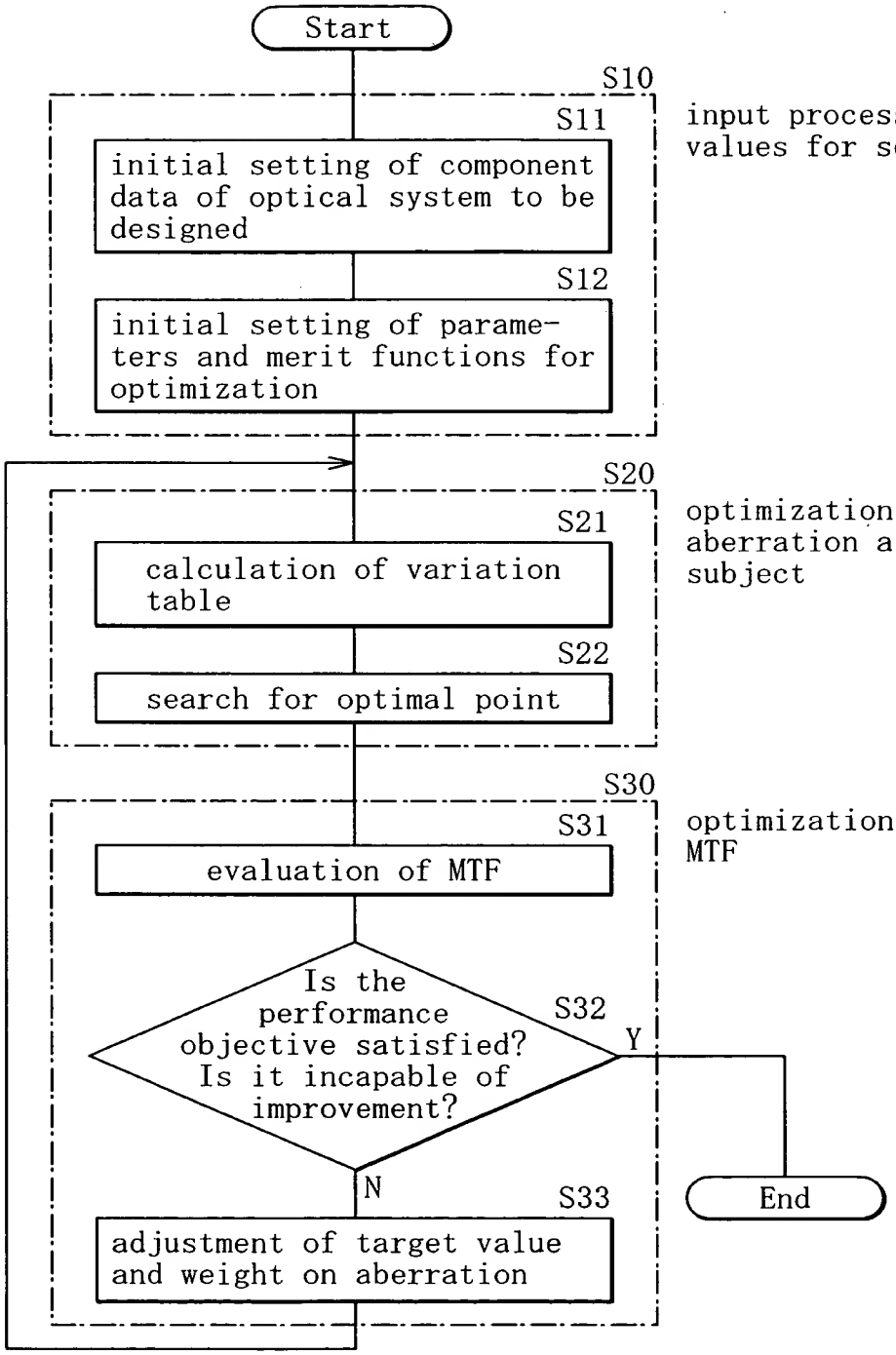
Start
S10
S11
initial setting of component data of optical system to be designed
S12
initial setting of parameters and merit functions for optimization
input process of various values for setting
S20
S21
calculation of variation table
S22
search for optimal point
optimization process with aberration as evaluation subject
S30
S31
evaluation of MTF
Is the performance objective satisfied? Is it incapable of improvement?
S32
Y
N
S33
adjustment of target value and weight on aberration
optimization process with MTF
End

FIG. 3

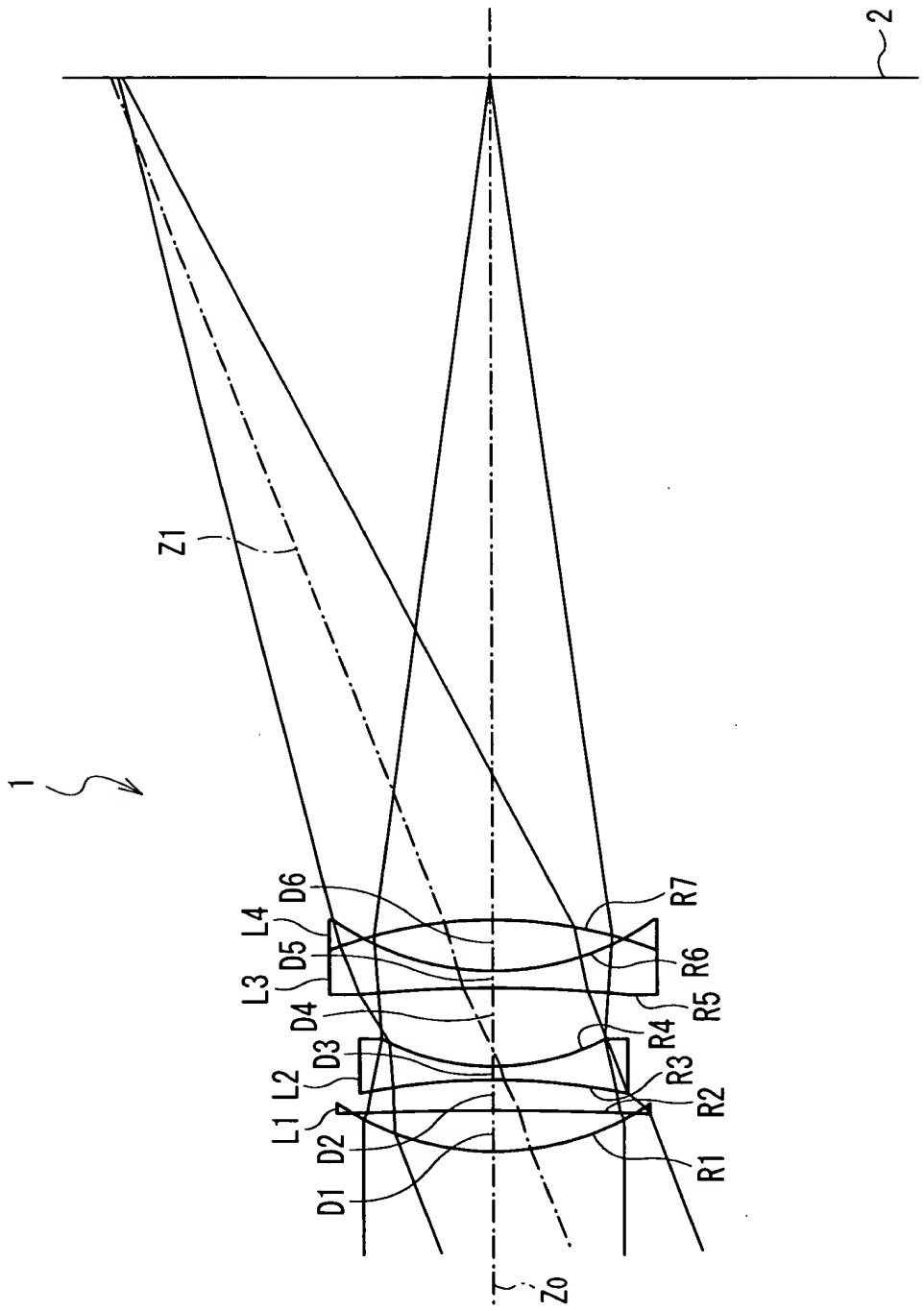

FIG. 4

Lens data at starting point				
Si (Surface No.)	Ri (Radius of curvature)	Di (Surface separation)	Ndi (Refractive index)	νdi (Abbe's No.)
1	13.1502	2.0817	1.60800	56.5
2	-128.4561	1.4724		
3	-30.7685	0.8631	1.56000	45.3
4	11.9825	4.0111		
5	-73.1134	0.8631	1.56000	45.3
6	12.6425	2.5894	1.61600	55.0
7	-20.0046	0.0000		

FIG. 5

Design condition	
Focal length f	50mm
Fno.	4.0
Location of object point	infinite
Half field angle ω	20°
Sample object point	center, half field angle of 14°, half field angle of 20°
Evaluation frequency for MTF	40cs/mm
Sample wavelength	435.8nm, 546.1nm, 656.3nm
Weight for wavelength	1 , 1 , 1
Distortion	within 1%
Vignetting	none

FIG. 6

Target value for MTF				
Field angle	Target 1		Target 2	
	S direction	T direction	S direction	T direction
Center	65%		57%	
14°	55%	65%	57%	65%
20°	55%	65%	57%	65%

FIG. 7

Result with Target 1						
Field angle	MTF		Adjustment ratio of weight		Target value for mean of longitudinal aberrations (μm)	
	S direction	T direction	S direction	T direction	S direction	T direction
Center	64%		1.2		13.6	
14°	55%	64%	1.5	1.1	11.7	-12.4
20°	54%	64%	0.7	1.8	-11.6	-34.2

FIG. 8

Result with Target 2						
Field angle	MTF		Adjudtment ratio of weight		Target value for mean of longitudinal aberrations (μm)	
	S direction	T direction	S direction	T direction	S direction	T direction
Center	56%		1.0		15.3	
14°	57%	65%	1.5	0.9	16.0	-10.7
20°	57%	64%	0.8	1.5	-10.8	-34.0

FIG. 9

Lens data of solution with Target 1				
Si (Surface No.)	Ri (Radius of curvature)	Di (Surface separation)	Ndi (Refractive index)	νdi (Abbe's No.)
1	18.9178	5.9592	1.79080	48.9
2	48.4813	2.0454		
3	-56.2882	2.0000	1.66405	32.6
4	17.1377	2.3758		
5	120.5964	2.0710	1.57937	40.1
6	20.0136	3.8850	1.80000	48.0
7	-34.3802	0.0000		

FIG. 10

Lens data of solution with Target 2				
Si (Surface No.)	Ri (Radius of curvature)	Di (Surface separation)	Ndi (Refractive index)	νdi (Abbe's No.)
1	18.4608	4.5462	1.80000	48.0
2	59.1162	2.3640		
3	-69.4418	2.0000	1.67159	32.1
4	16.3997	2.8414		
5	294.9039	2.2763	1.57555	40.8
6	20.8082	3.9552	1.80000	48.0
7	-35.6773	0.0000		

FIG. 11

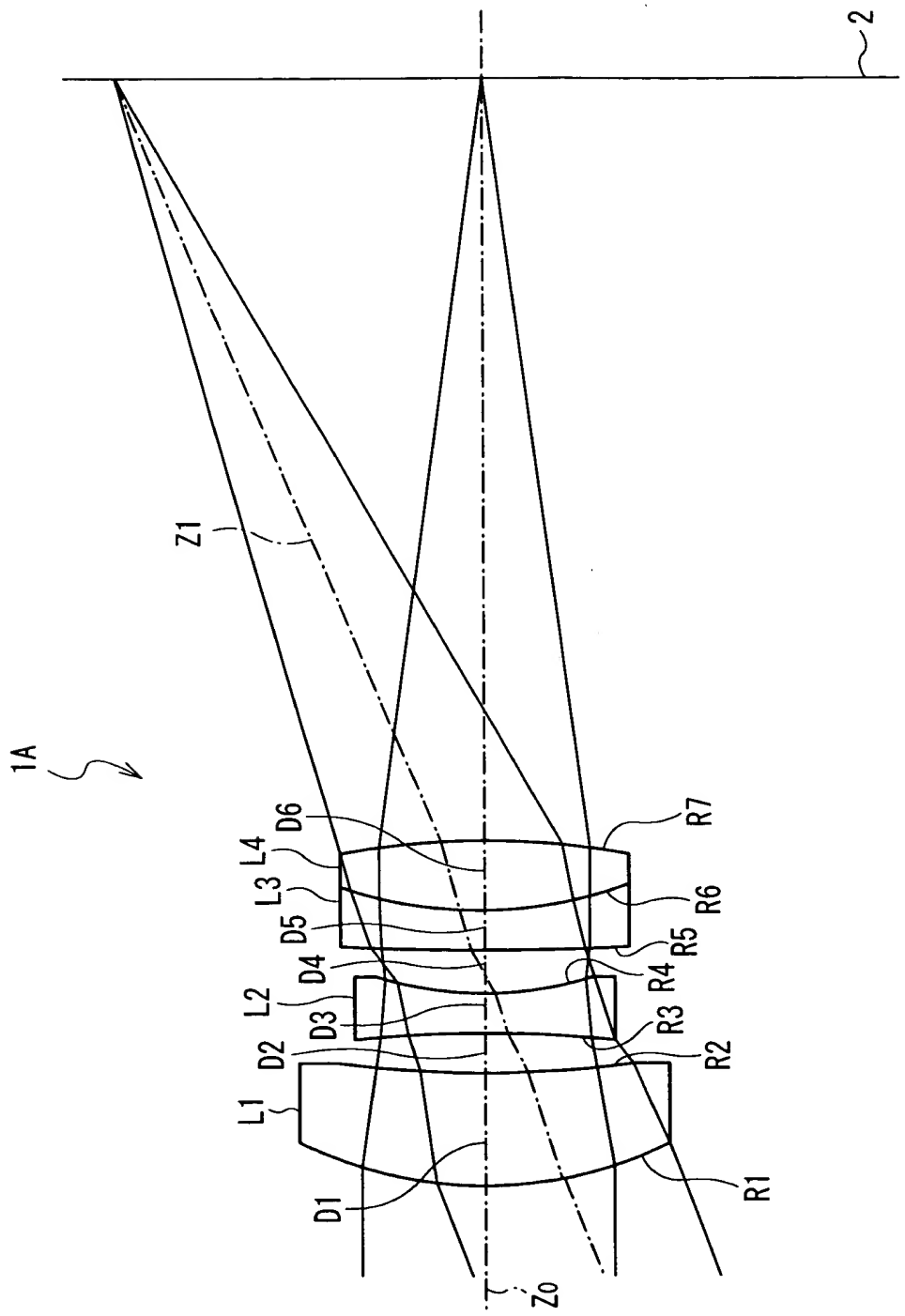

FIG. 12

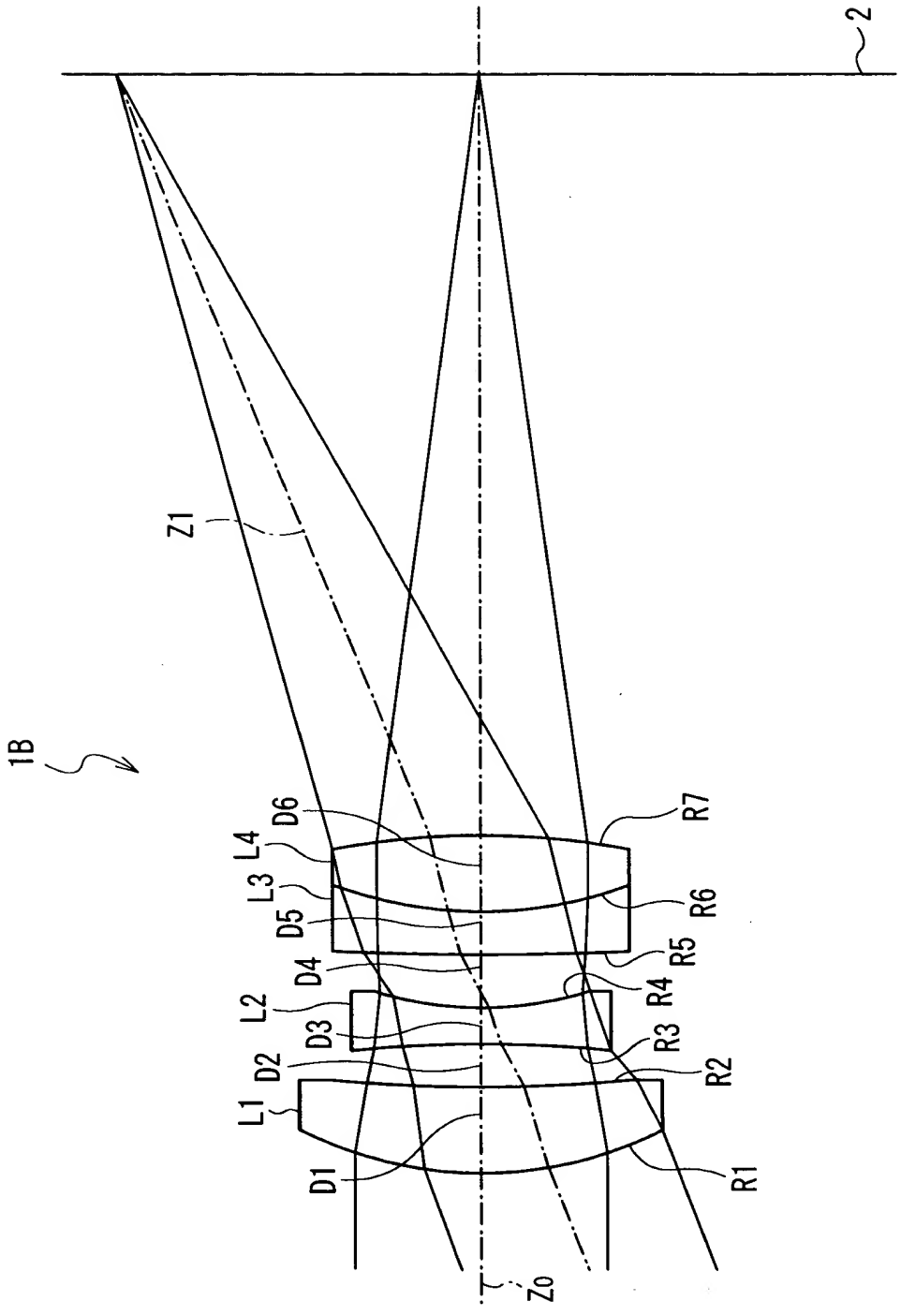

FIG. 13

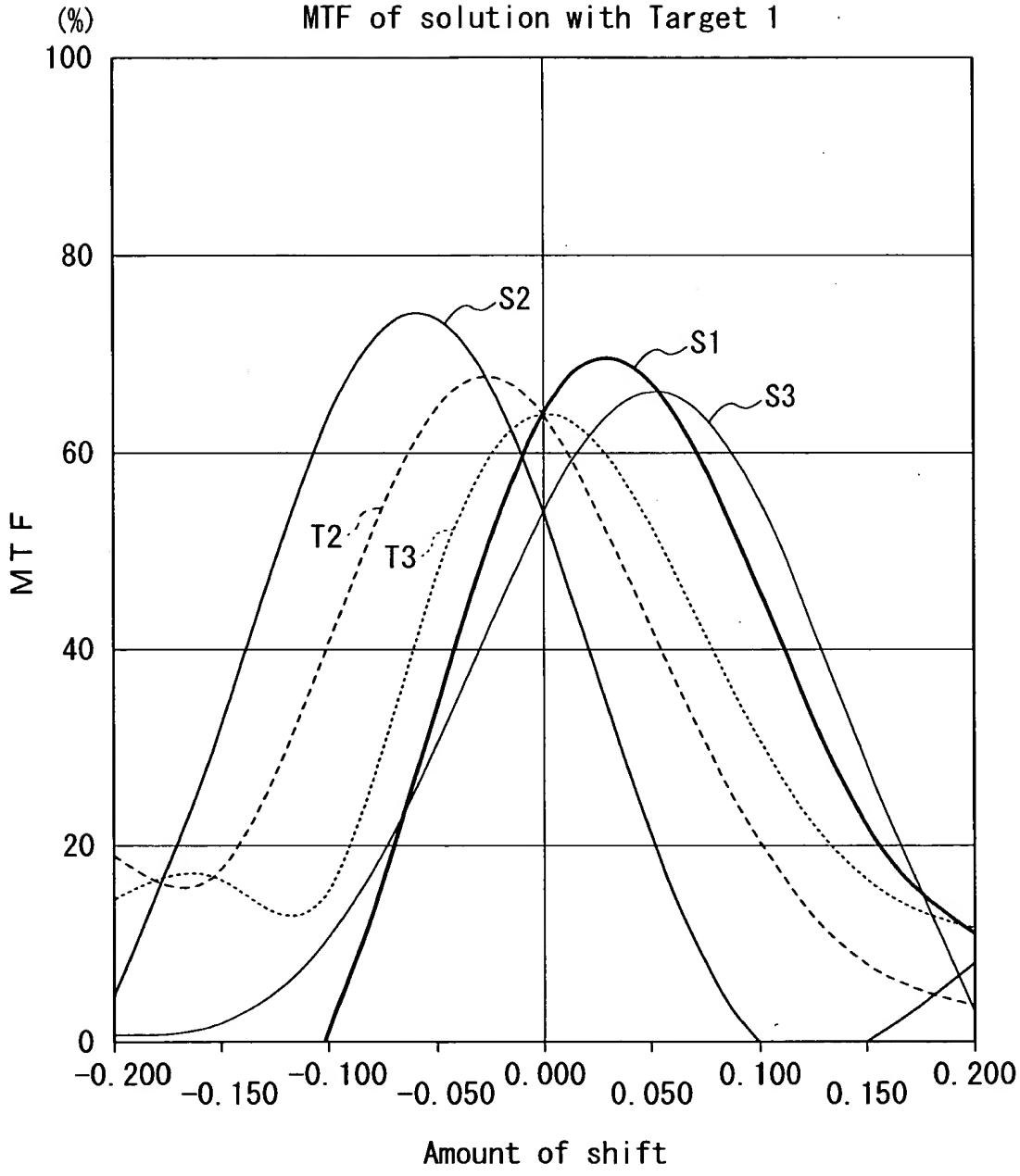
MTF of solution with Target 1
(%)
100
80
60
40
20
0
MTF
S2
S1
S3
T2
T3
-0.200
-0.150
-0.100
-0.050
0.000
0.050
0.100
0.150
0.200
Amount of shift

FIG. 14

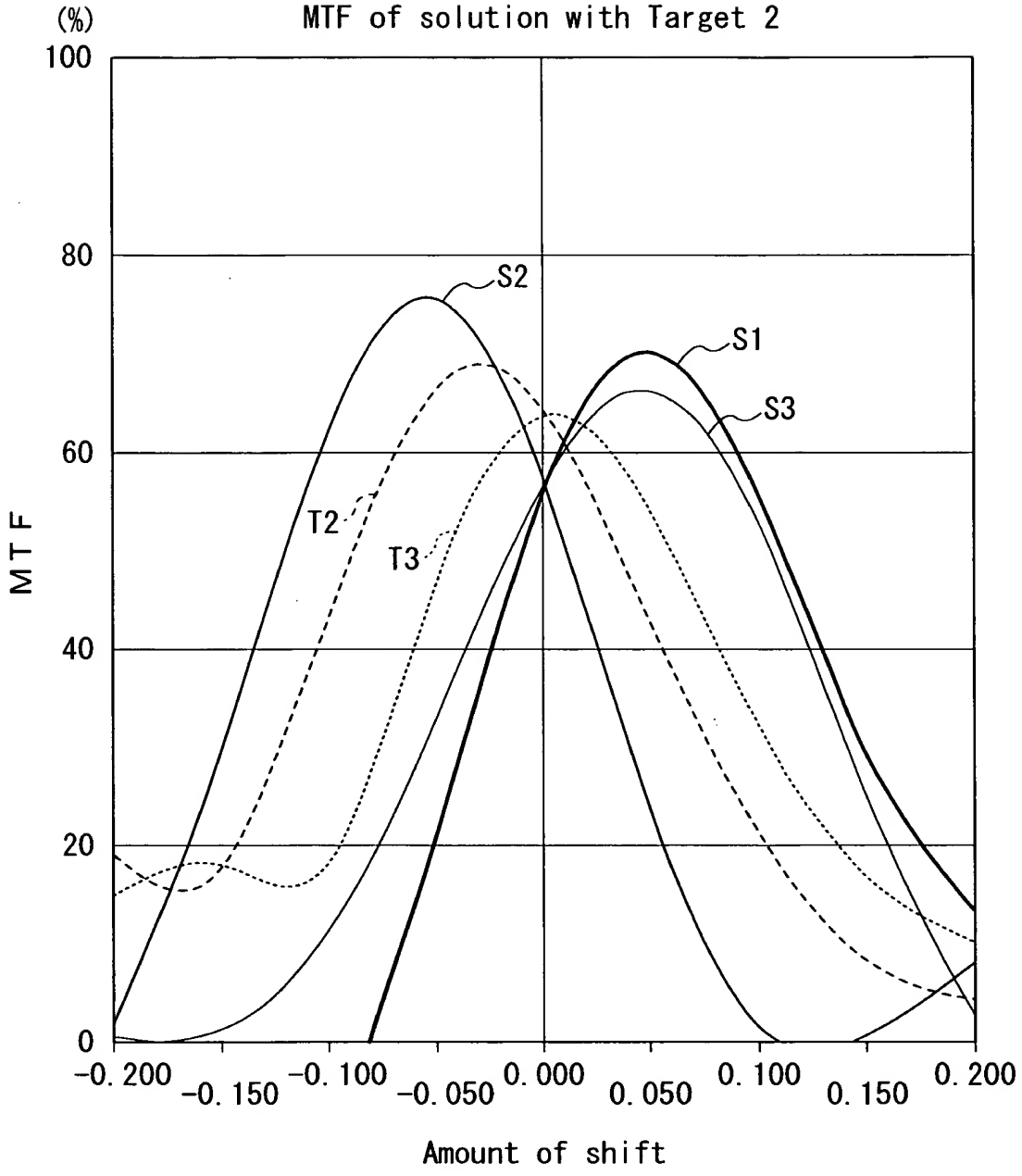
MTF of solution with Target 2
(%)
100
80
60
40
20
0
MTF
S1
S2
S3
T2
T3
-0.200
-0.150
-0.100
-0.050
0.000
0.050
0.100
0.150
0.200
Amount of shift

FIG. 15

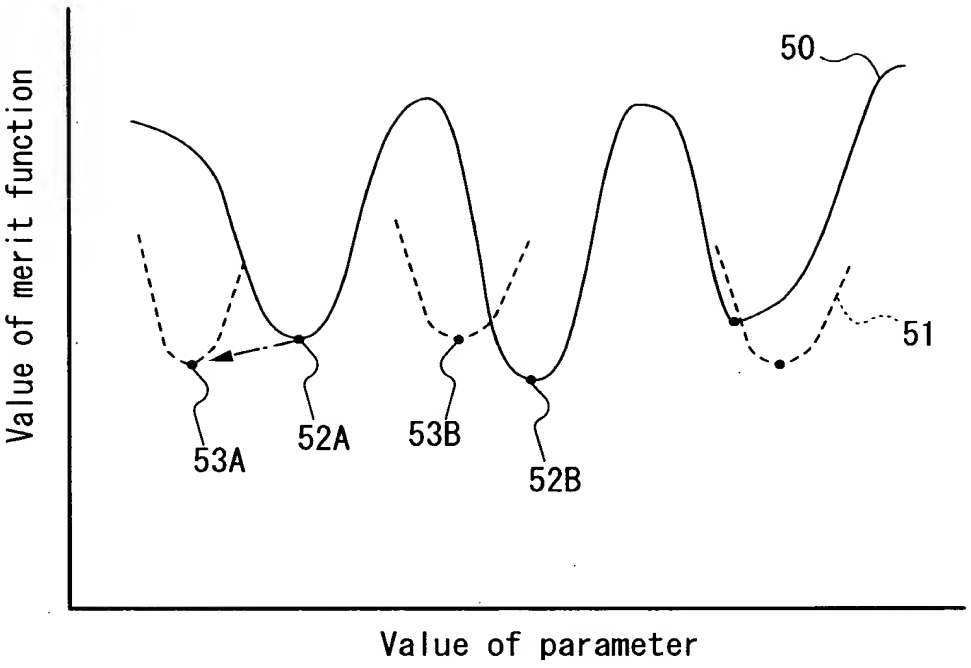
Value of merit function
50
51
53A
52A
53B
52B
Value of parameter

FIG. 16

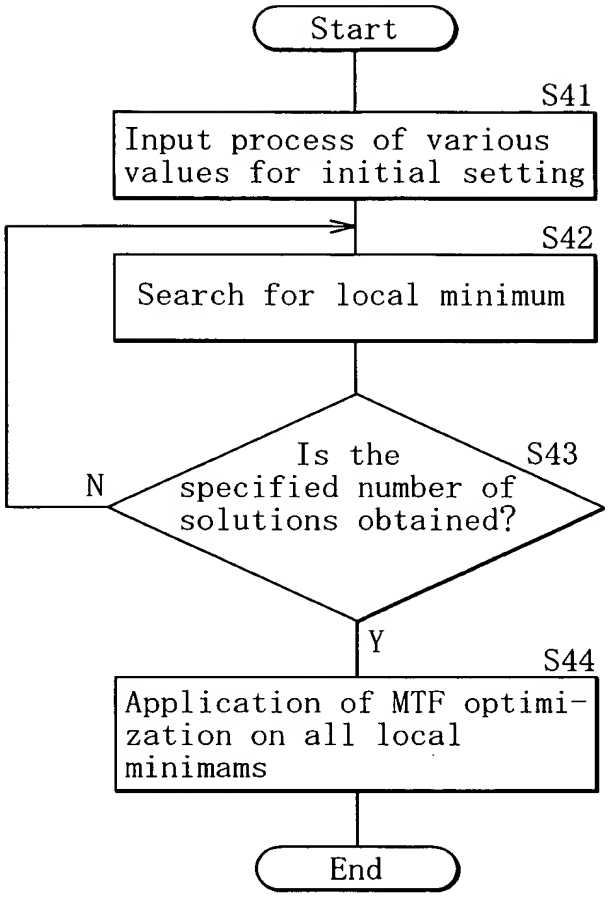
Start
S41
Input process of various values for initial setting
S42
Search for local minimum
Is the specified number of solutions obtained?
S43
N
Y
S44
Application of MTF optimization on all local minimams
End

FIG. 17

Target value for MTF		
Field angle	Target	
	S direction	T direction
Center	65%	
14°	55%	65%
20°	60%	65%

FIG. 18

Solution No.	Value of merit function	
	Aberration	M T F
1	0.001598	10.3%
2	0.001543	10.7%
3	0.001539	2.7%
4	0.001549	7.7%
5	0.001539	6.5%

FIG. 19

Lens data of solution No.3				
S i (Surface No.)	R i (Radius of curvature)	D i (Surface separation)	N d i (Refractive index)	ν d i (Abbe's No.)
1	19.8762	5.4071	1.80000	43.8
2	-282.4339	1.6230		
3	-43.4813	2.0000	1.72558	30.2
4	16.8887	3.6591		
5	-127.0678	2.0000	1.67193	44.0
6	19.2644	5.2366	1.80000	48.0
7	-28.2142	0.0000		

FIG. 20

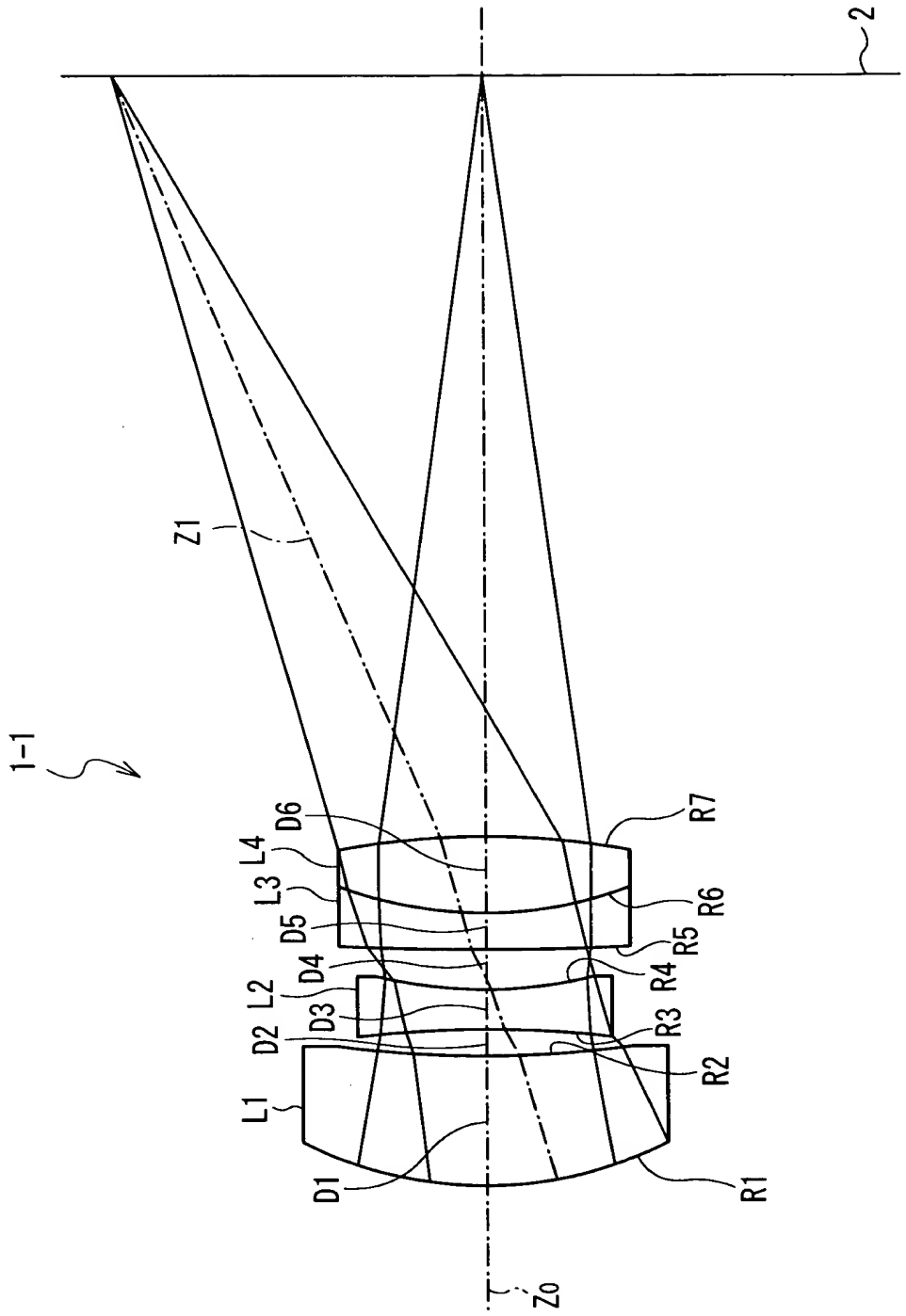

FIG. 21

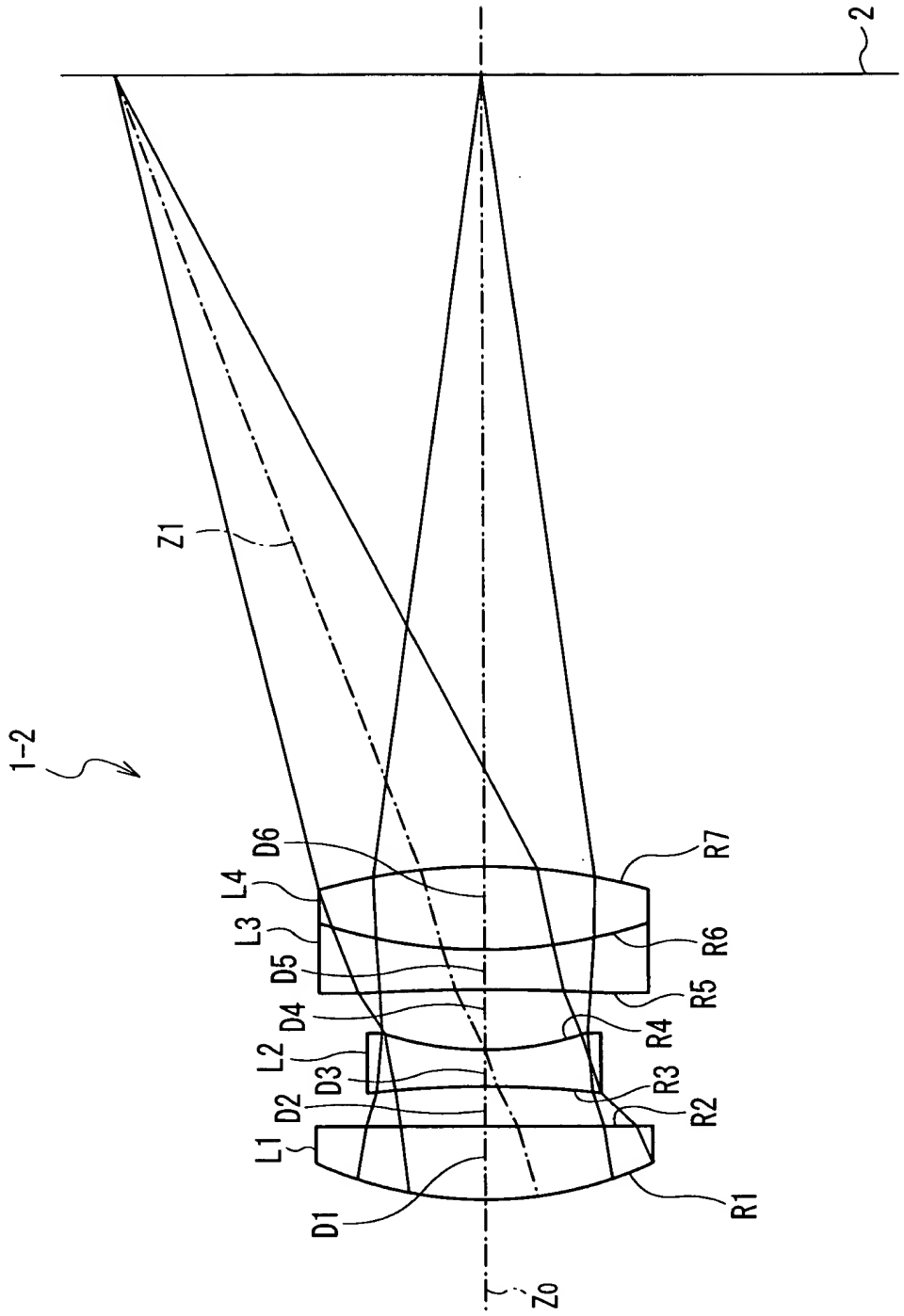

FIG. 22

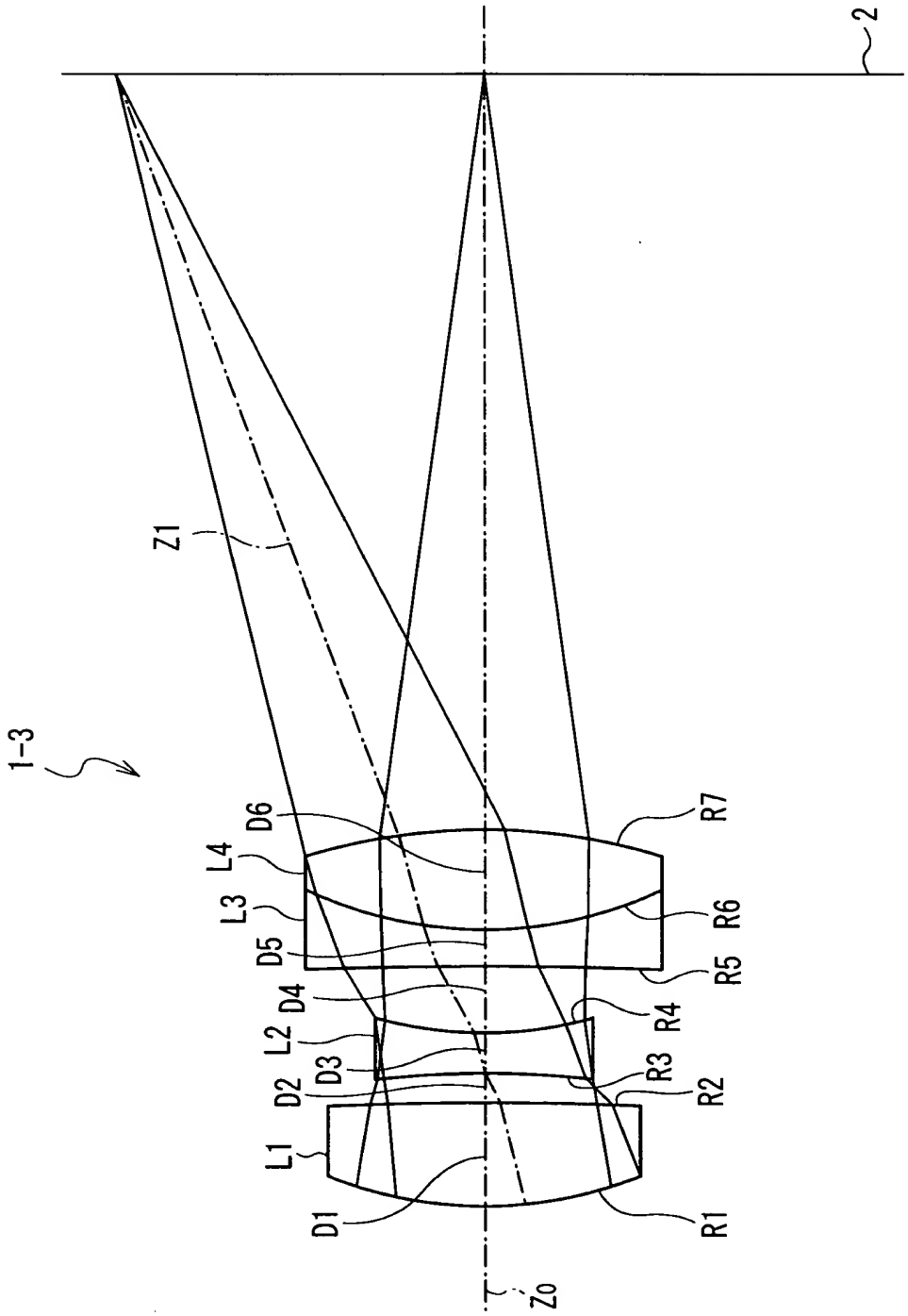

FIG. 23

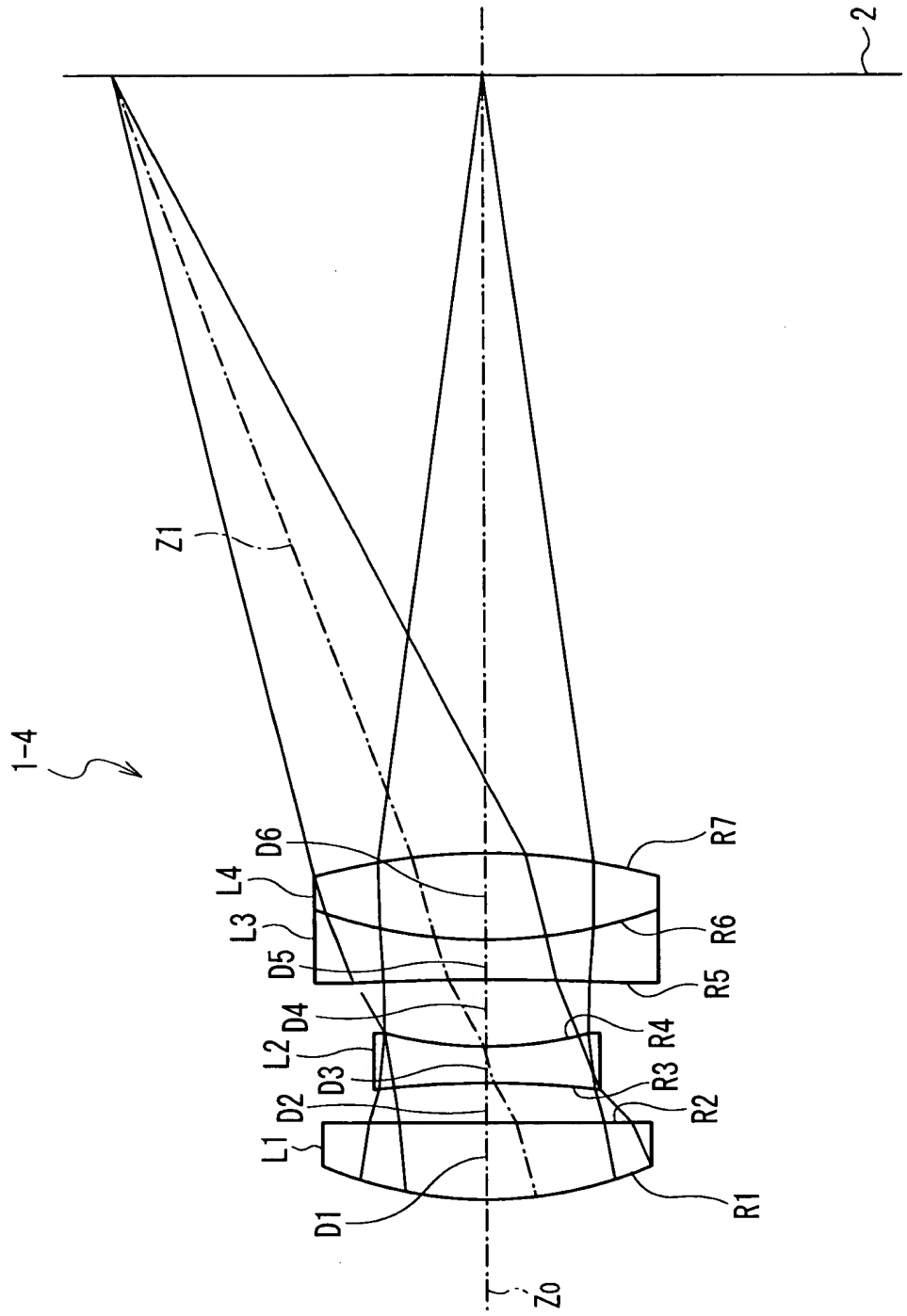

FIG. 24

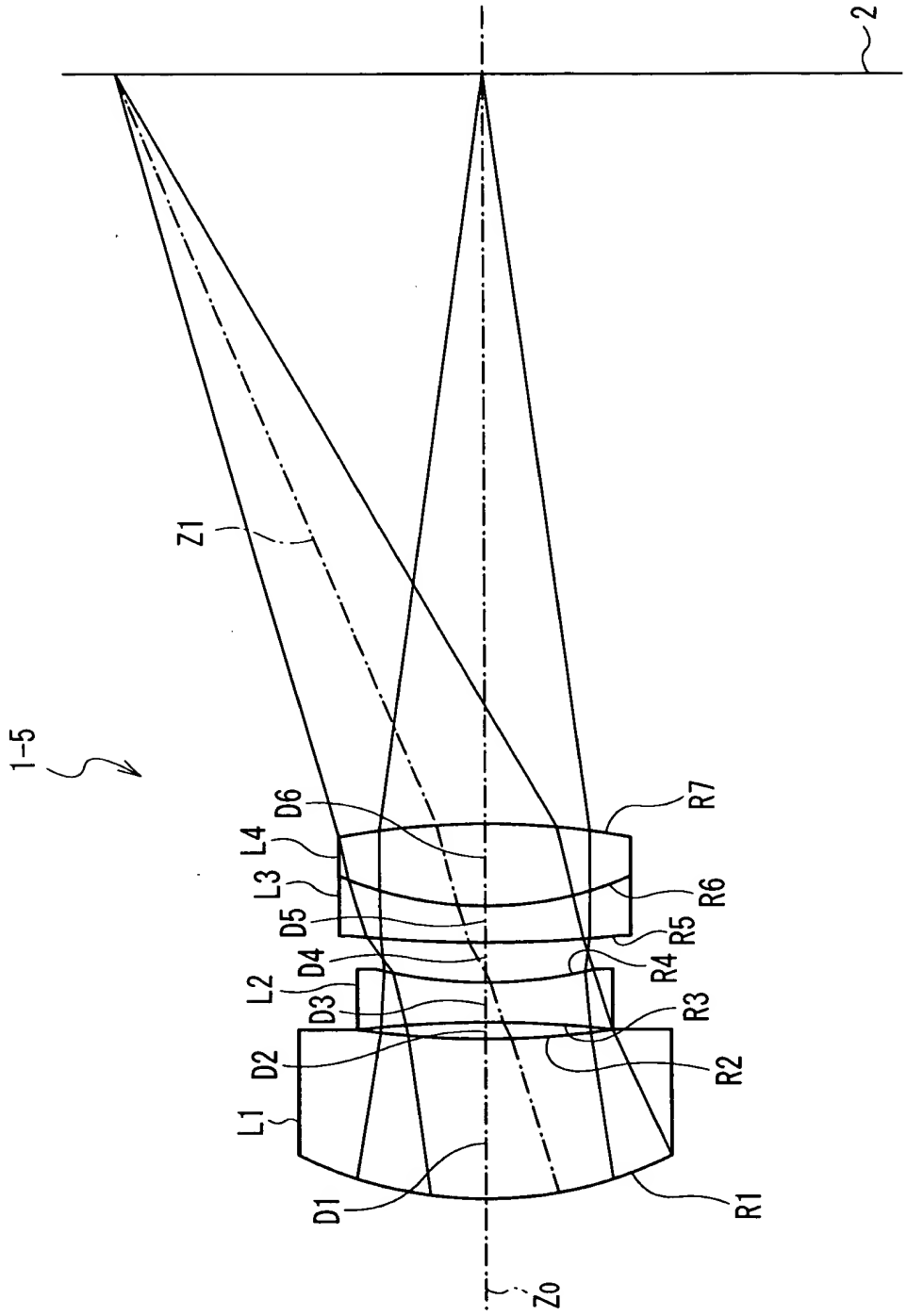

FIG. 25

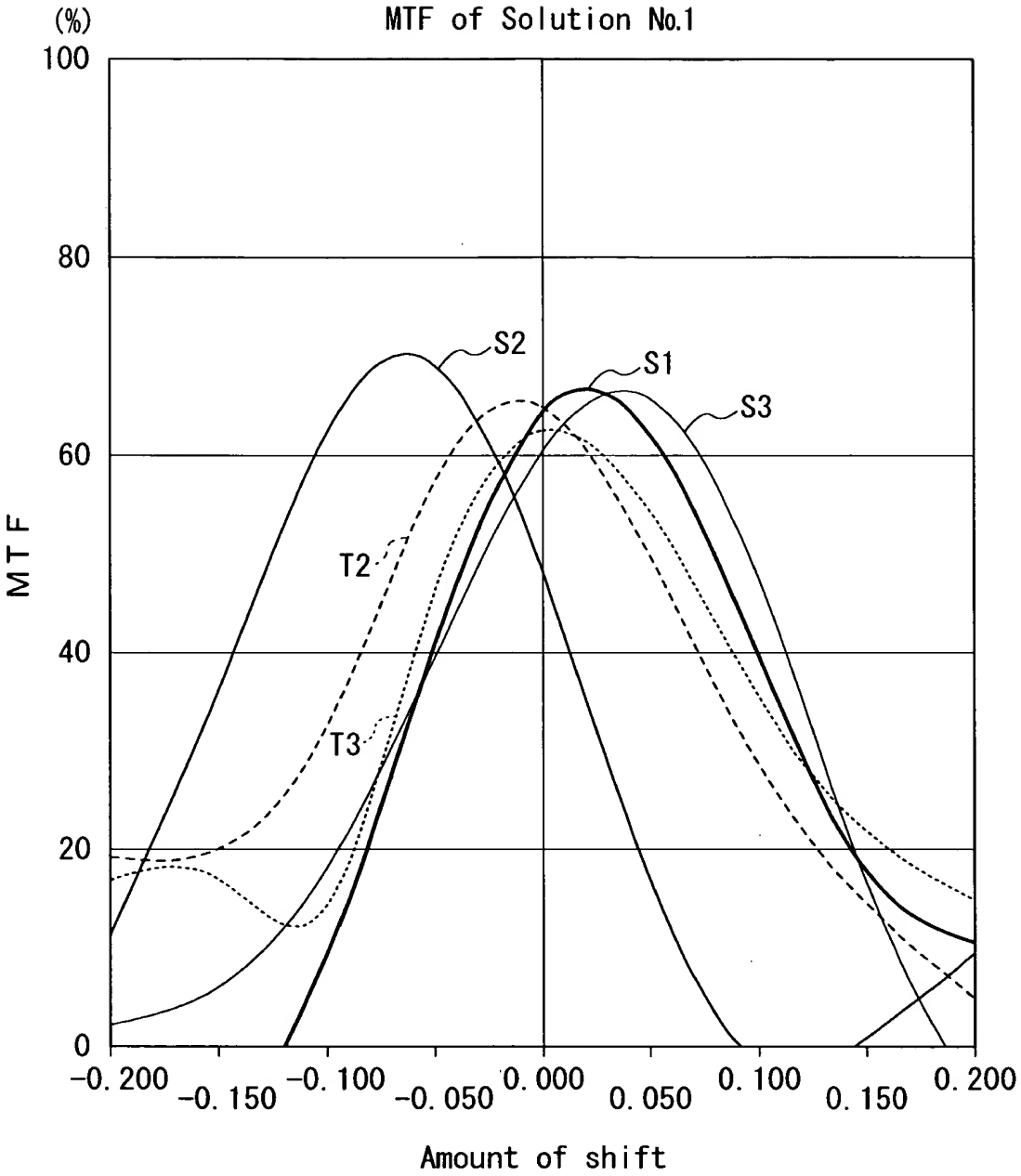
MTF of Solution No.1
(%)
100
80
60
40
20
0
MTF
S1
S2
S3
T2
T3
-0.200
-0.150
-0.100
-0.050
0.000
0.050
0.100
0.150
0.200
Amount of shift

FIG. 26

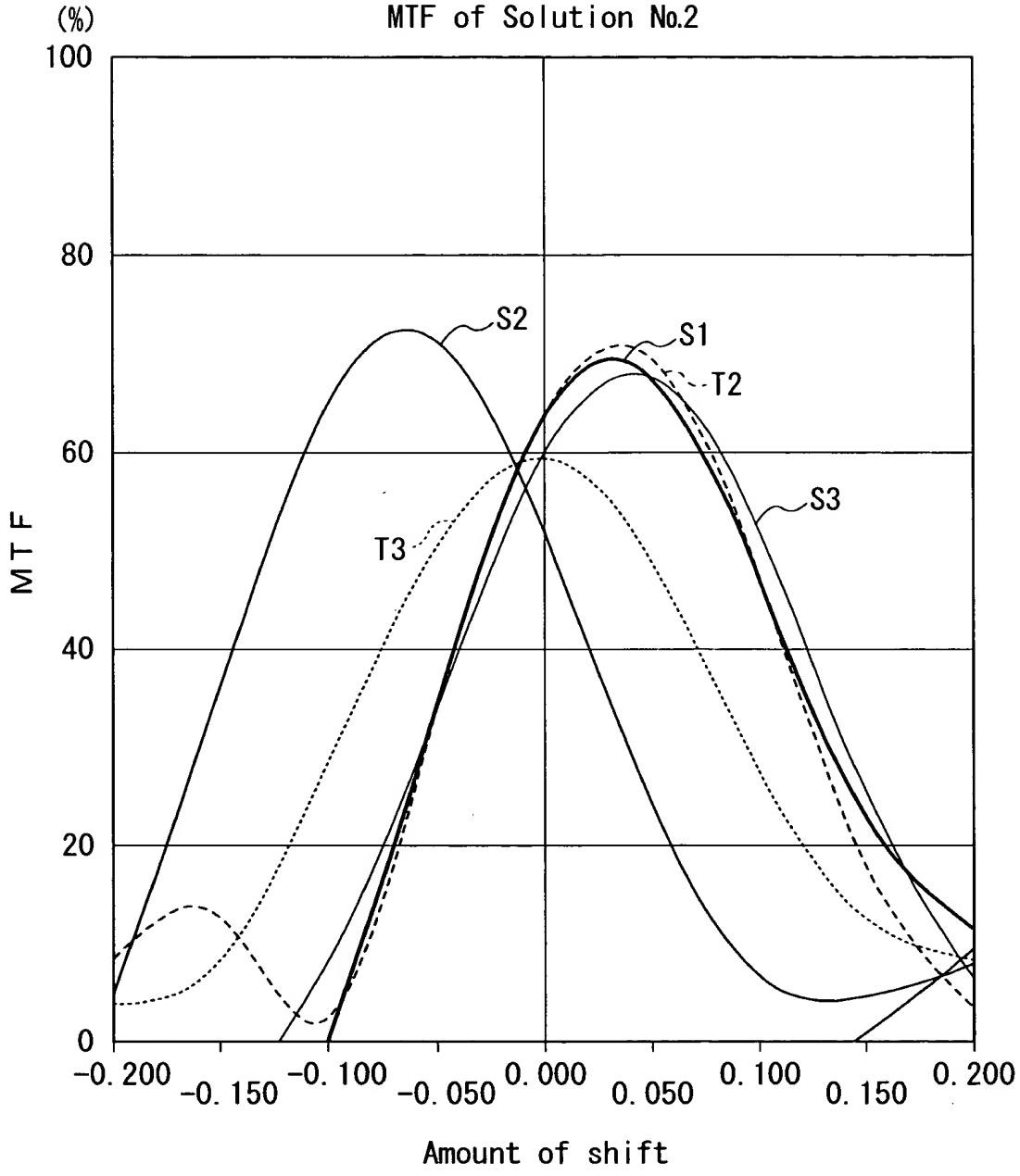
MTF of Solution No.2
(%)
100
80
60
40
20
0
MTF
S1
S2
S3
T2
T3
-0.200
-0.150
-0.100
-0.050
0.000
0.050
0.100
0.150
0.200
Amount of shift

FIG. 27

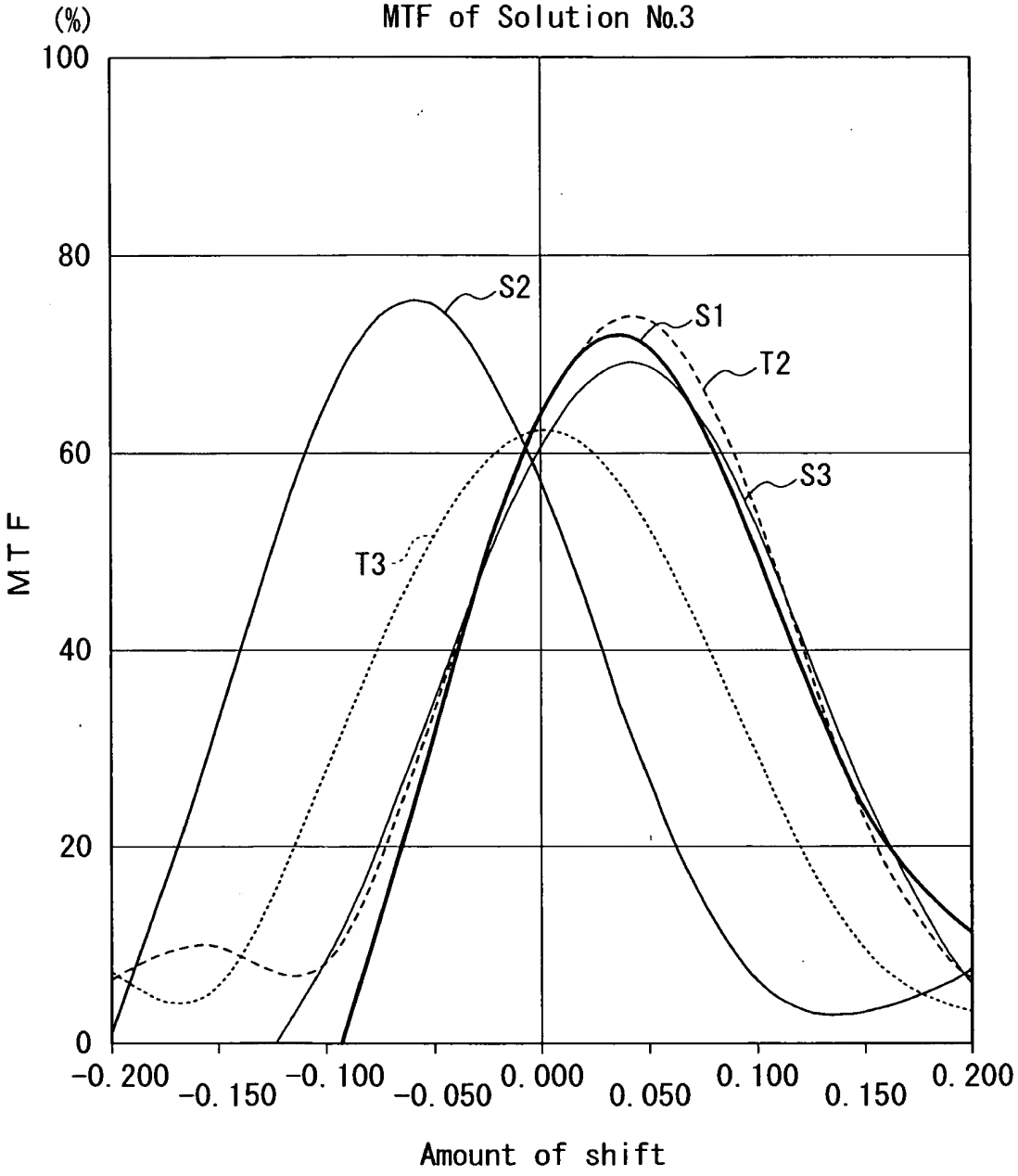
MTF of Solution No.3
(%)
100
80
60
40
20
0
MTF
S1
S2
S3
T2
T3
-0.200
-0.150
-0.100
-0.050
0.000
0.050
0.100
0.150
0.200
Amount of shift

FIG. 28

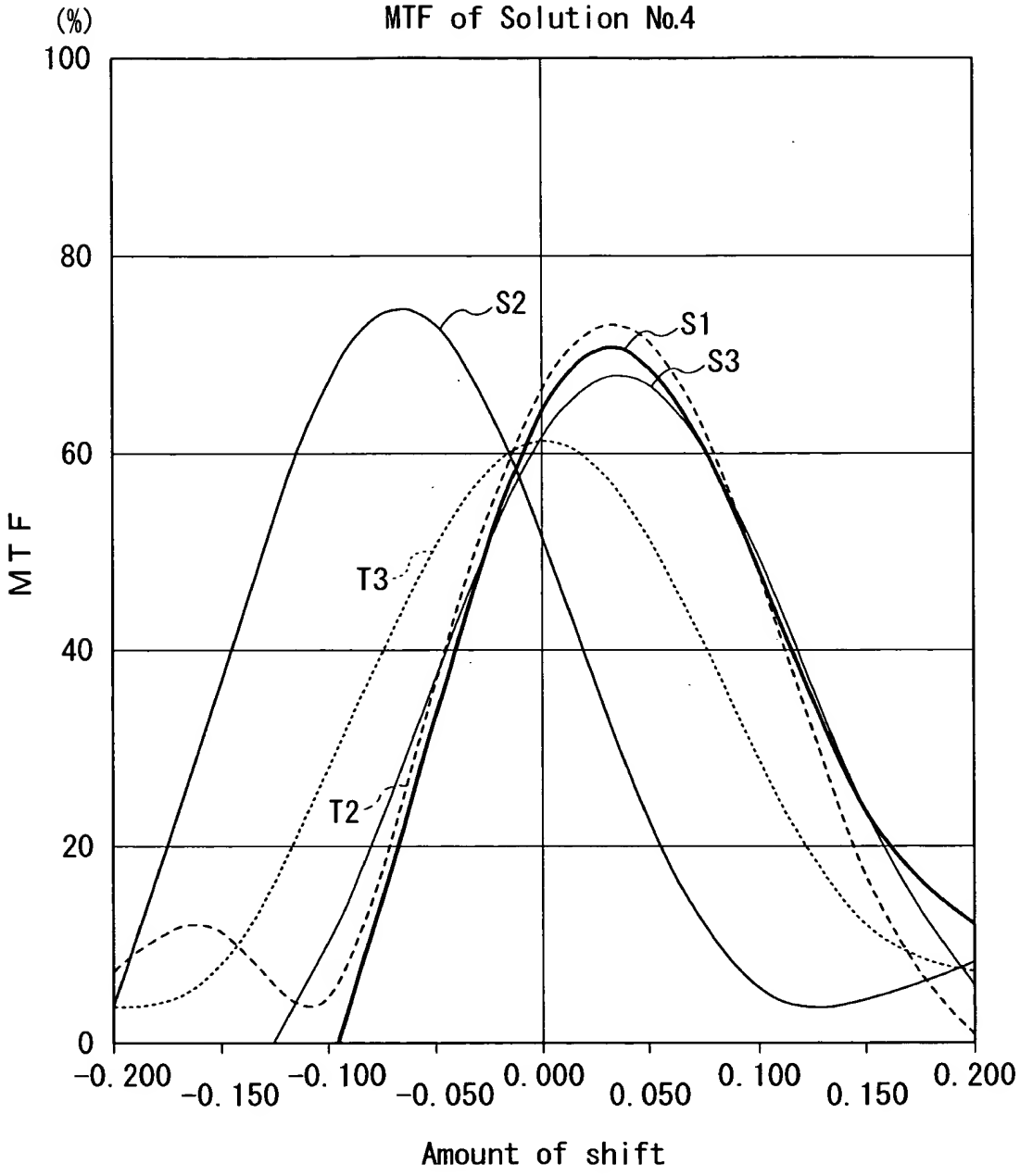
MTF of Solution No.4
(%)
100
80
60
40
20
0
MTF
S1
S2
S3
T2
T3
-0.200
-0.150
-0.100
-0.050
0.000
0.050
0.100
0.150
0.200
Amount of shift

FIG. 29

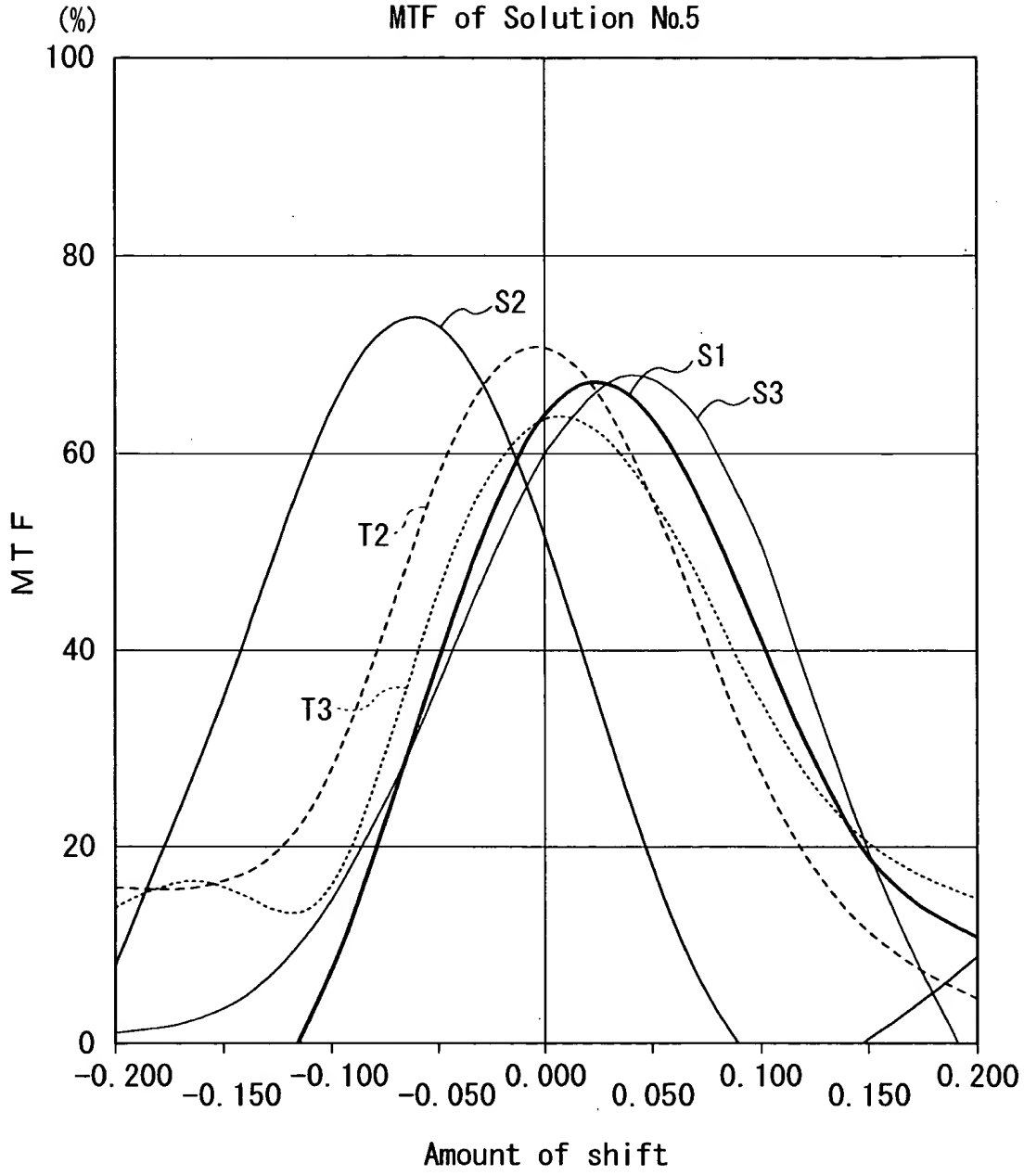
MTF of Solution No.5
(%)
100
80
60
40
20
0
MTF
S1
S2
S3
T2
T3
-0.200
-0.150
-0.100
-0.050
0.000
0.050
0.100
0.150
0.200
Amount of shift

FIG. 30